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USAARL REPORT NO. 70-2

REAL-EAR SOUND ATTENUATION CHARACTERISTICS OF
CBS LABORATORIES' MARK II EARPHONE INCLOSURES

By

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and

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JULY 1969

U. S. ARMY AEROMEDICAL RESEARCH LABORATORY

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ABSTRACT

The real-ear attenuation characteristics of the CBS Laboratories' MARK II earphone inclosures were determined by standard procedures and equipment specified by ASI Z24.22-1957. The inclosures were mounted in an Army APH-5 helmet. The results of the tests show that the MARK II earphone inclosures do improve the attenuation characteristics of the APH-5 at frequencies from 75 to 500 Hz. At higher frequencies between 3 K and 8 K Hz the attenuation was less than that offered by the standard APH-5 earmuff. A comparison of the overall sound attenuation characteristics of the MARK II inclosures and the SPH-3 (Modified) shows that the latter has superior attenuation characteristics.

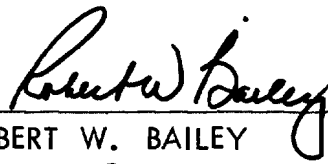
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REAL-EAR SOUND ATTENUATION CHARACTERISTICS OF CBS LABORATORIES' MARK II EARPHONE INCLOSURES

INTRODUCTION.

In most operational situations the acoustical environments around U. S. Army Aviation personnel are a potential hazard, as established by criterion of Army Technical Bulletin TB MED 251, 25 January 1965. Results of spectra analyses of various types of U. S. Army aircraft have aided in establishing that there are high sound pressure levels of aircraft and weapons noise against which the personnel must be protected. USAARL Reports Nos. 66-6 and 67-6 show that the standard Army APH-5 Crash Protective Helmet contains earphone inclosures of relatively inferior sound attenuation characteristics.

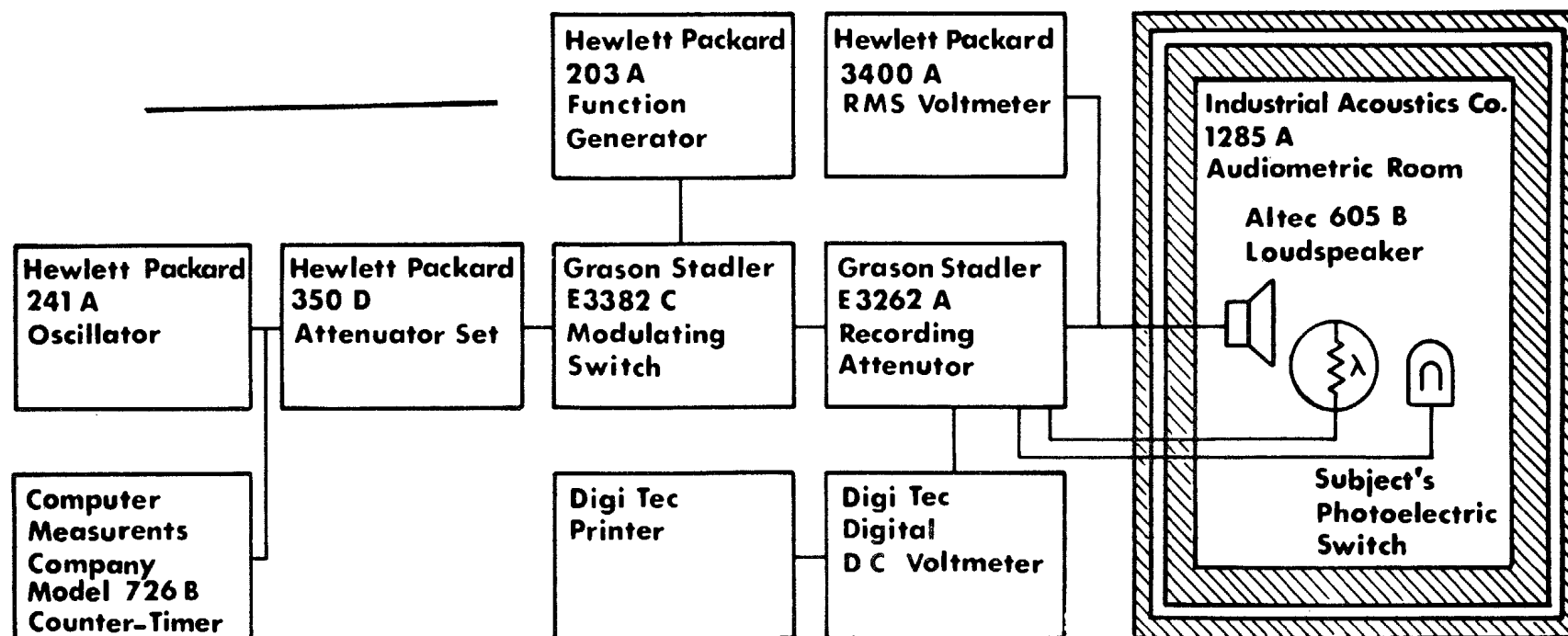
The results of other tests conducted at the Aeromedical Research Laboratory are reported in USAARL Report No. 67-8, which reports the efficient sound attenuation characteristics of the Navy SPH-3 (Modified) (LS) Helmet. As a result of the recommendations in this report and other efforts within the Aeromedical Research Laboratory, the modified version of the SPH-3 helmet - the SPH-4, has been purchased by the U. S. Army. In the meantime, the efforts of Natick Laboratories to improve the attenuation characteristics of the standard APH-5 helmet have been manifested by development of special earphone inclosures by CBS Laboratories. This project, monitored by ECOM at Ft. Monmouth, New Jersey, has resulted in a request by that laboratory for real-ear attenuation tests to be accomplished at USAARL. In compliance with this request, a standard real-ear attenuation test was conducted.

PROCEDURE AND EQUIPMENT.

Procedures, equipment and physical requirements specified in the standard method for the measurement of the real-ear attenuation of ear protectors at threshold, ASI Z24.22-1957, were used for ascertaining the real-ear attenuation characteristics of the CBS MARK II earphone inclosures.

In addition to the standard 125, 250, 500, 1K, 2K, 3K, 4K, 6K and 8K Hz test frequencies, one lower test tone 75 Hz was included. The tones were generated by a Hewlett-Packard 241 A oscillator. See Block Diagram of instruments in Figure 1. The output of the oscillator was connected to a step attenuator set - a Hewlett-Packard 350 D with a range of 110 db in 1 db steps. This attenuator provided the experimenter with a calibrated control of test tone levels for checking the subjects' reliability; also, the control of the overall sound pressure levels of test tones was necessary for subjects with extremely low thresholds and for boosting levels when testing attenuating devices of high efficiency. The output of the 350 D attenuator was fed into the input of a Grason Stadler E-3382C modulating switch. The modulating switch served as a device for interrupting the test tones with a 50 percent duty cycle and with off and on durations of approximately 370 milliseconds which simulates the interruption rate of our Laboratory audiometer. The rise and decay times of the switch were 40 milliseconds each. The E-3382 C modulating switch also served as a power amplifier for driving the loudspeaker. The Grason Stadler E-3262 A recording attenuator was between the power amplifier and loudspeaker for recording and control of output level of the loudspeaker. The loudspeaker was an Altec 605 B, a two-way duplex 15 inch loudspeaker. The recording attenuator was provided with control switches that may be operated by the subject and the experimenter. The subject's switch was a photoelectric clickless type. The experimenter's switch has facilities for changing directions, stopping the attenuator and overriding the subject's control. Having the recording attenuator on the output of the power amplifier provides attenuation of the test signal and the amplifier noise. The voltage to the loudspeaker was measured with a Hewlett-Packard 3400 A RMS voltmeter. The circuitry was calibrated with this voltmeter at the beginning of each test.

In addition to the recording information on the recording attenuator paper, there is a digital printout of the attenuation values. A potentiometer was coupled mechanically to the recording attenuator which controlled a DC voltage as a function of attenuator setting. The voltage across the potentiometer was adjusted to indicate 1.000 volt on a Digi Tec digital DC voltmeter when the recording attenuator was set at 100 db attenuation. By arbitrarily moving the decimal point, the voltage indication may be taken as a representation of the attenuation value of 100.0 db. The linear relationship between the change of attenuation of the recording attenuator and the accompanying voltage across the potentiometer yields digital voltage readings that are numerically identical to attenuation values registered on the recording attenuator. This information was printed by a Digi Tec printer which was connected to the digital voltmeter. This arbitrary system of representing attenuation values with voltage readings has a resolution equivalent to one-tenth decibel.



BLOCK DIAGRAM OF INSTRUMENTATION FOR REAL-EAR ATTENUATION TEST

Figure 1

The recording attenuator circuitry was provided with a one-shot monostable multi-vibrator circuit that sent a print command each time the subject changed recording attenuator direction. With a Bekesy type response for constant test tones, there was an oscillation of attenuation values around the subject's threshold. This oscillation is due to the activation and release of the attenuator control switch when the listener perceives and ceases to perceive the acoustic stimuli, respectively. The printout facility provided digital printout of minimum and maximum values of the oscillations around the subject's threshold. The printer also provided a sum total of the response values at the end of ten responses.

A quiet environment was provided by the Industrial Acoustic Company 1285-A double wall audiometric room. The intensity gradients were measured for certain test tones as required by the ASI Z24.22-1957. Tables I through III contain sound pressure levels measured in 1-inch increments along three axes from the subject's head. These were the normal maximal sound pressure values of each test tone after calibration. The 1285-A had extremely high attenuation characteristics throughout the audiospectrum. Table IV is a tabulation of a one-third octave band statistical analysis of the room noise. The system noise of the instrumentation used to measure the room noise is also shown. The noise measure instrumentation was a calibrated one-inch Brüel & Kjaer microphone, a Brüel & Kjaer audiofrequency spectrometer type 2112, a Brüel & Kjaer level recorder type 2305, and a Brüel & Kjaer statistical distribution analyzer type 4420. System noise measurements were done with the microphone cartridge replaced by 50 pico farad capacitor.

RESULTS AND DISCUSSION.

Table V and Figure 2 show the results of the real-ear attenuation test on the CBS MARK II earphone inclosure. Comparison of these attenuation characteristics with the characteristics of the Navy SPH-3 (Modified) (LS) helmet shows that the real-ear attenuation of the MARK II is almost identical to the values obtained at test frequencies between 50 and 500 Hz with the SPH-3 (Modified). But at all other test frequencies the MARK II attenuation values were inferior. At 75, 125, 1K, 2K, 3K, 4K, 6K and 8K Hz test frequencies, the MARK II is not as efficient as the SPH-3 (Modified). With the use of a decile rank system (see Table VI) that was established in USAARL Report 66-6, the relative efficiency of the two ear protective devices is shown in Figure 3. These curves show that, when compared with what has been accomplished among various types of ear protective devices, the MARK II is perhaps most inefficient at 75 and 1K Hz, - not to mention the considerable differences of decile rank values at

Table I

Sound Pressure Level Gradient Data Derived from Measurements of Ten Test Tones in the IAC 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. The Values are Normal Maximum Sound Pressure Level Output, in Decibels (re 0.0002 Dyne/cm²), from the Calibrated Instrumentation for Testing Real-Ear Attenuation.

Test Tones in Hz	Distance in Inches Below the Normal Head Position						Normal Head Position	Distance in Inches Above the Normal Head Position						
	<u>6"</u>	<u>5"</u>	<u>4"</u>	<u>3"</u>	<u>2"</u>	<u>1"</u>		<u>0</u>	<u>1"</u>	<u>2"</u>	<u>3"</u>	<u>4"</u>	<u>5"</u>	<u>6"</u>
S	75	70.5	70.6	70.8	71.2	71.4	71.6	71.8	71.7	71.8	72.1	72.3	72.3	72.5
	125	77.2	77.6	77.8	77.8	78.0	78.2	78.5	78.5	78.7	79.0	79.2	79.4	79.6
	250	84.3	84.3	84.1	83.6	83.4	82.9	82.8	82.6	82.4	82.0	81.8	81.6	81.5
	500	89.4	89.3	89.1	89.0	88.9	88.6	88.6	88.5	88.5	88.6	88.6	88.7	88.8
	1000	84.9	84.8	84.6	84.4	85.2	85.6	86.2	86.2	86.0	85.7	85.4	84.7	84.3
	2000	85.6	85.8	85.5	84.6	84.0	84.2	84.8	84.9	84.8	84.4	84.0	84.4	85.0
	3000	83.8	83.4	85.6	86.2	85.4	83.4	85.0	86.6	87.3	85.8	84.8	85.0	85.2
	4000	84.1	85.0	84.8	85.4	87.8	87.0	85.2	85.4	84.6	84.4	84.8	84.0	82.1
	6000	72.6	71.7	72.8	77.8	80.5	84.2	82.0	82.0	80.6	76.4	78.1	77.2	77.3
	8000	79.2	78.0	77.9	81.1	81.8	83.4	83.6	84.2	85.1	82.4	84.4	81.1	83.0

Table II

Sound Pressure Level Gradient Data Derived from Measurements of Ten Test Tones in the IAC 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. The Values are Normal Maximum Sound Pressure Level Output, in Decibels (re 0.0002 Dyne/cm²), from the Calibrated Instrumentation for Testing Real-Ear Attenuation.

Test Tones in Hz	Distance in Inches in Front of the Normal Head Position						Normal Head Position	Distance in Inches Behind the Normal Head Position					
	<u>6"</u>	<u>5"</u>	<u>4"</u>	<u>3"</u>	<u>2"</u>	<u>1"</u>		<u>1"</u>	<u>2"</u>	<u>3"</u>	<u>4"</u>	<u>5"</u>	<u>6"</u>
75	76.7	76.1	75.4	74.6	73.9	73.3	72.2	71.4	70.7	70.0	69.2	68.6	68.3
125	81.1	80.6	80.4	80.0	79.6	79.2	78.6	78.4	78.1	77.8	77.2	77.4	76.6
250	80.8	81.5	82.8	81.9	82.6	82.8	83.0	83.2	83.5	83.6	83.7	83.7	83.6
500	87.2	87.8	88.0	88.4	88.5	88.5	88.2	88.1	87.9	87.6	87.3	86.7	86.6
1000	86.0	84.6	83.4	83.7	84.7	86.0	86.6	86.5	85.8	84.6	83.3	82.4	82.5
2000	83.4	84.2	86.7	85.7	81.8	82.9	85.3	84.0	80.0	82.0	84.2	83.4	81.3
3000	82.6	83.8	83.4	83.6	85.3	82.0	82.6	80.2	78.8	83.3	79.5	84.4	85.8
4000	84.9	85.7	85.5	85.3	85.8	84.3	84.5	82.6	85.0	84.1	83.0	83.2	81.2
6000	78.0	81.4	80.6	77.8	79.0	81.2	82.8	72.6	77.8	80.8	82.0	75.0	77.8
8000	79.6	78.6	82.6	82.0	82.0	82.7	82.4	80.1	80.6	80.2	82.1	79.8	80.6

Table III

Sound Pressure Level Gradient Data Derived from Measurements of Ten Test Tones in the IAC 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. The Values are Normal Maximum Sound Pressure Level Output, in Decibels (re 0.0002 Dyne/cm²), from the Calibrated Instrumentation for Testing Real-Ear Attenuation.

Test Tones in Hz	Distance in Inches Left of the Normal Head Position						Normal Head Position	Distance in Inches Right of the Normal Head Position					
	<u>6"</u>	<u>5"</u>	<u>4"</u>	<u>3"</u>	<u>2"</u>	<u>1"</u>		<u>1"</u>	<u>2"</u>	<u>3"</u>	<u>4"</u>	<u>5"</u>	<u>6"</u>
75	71.6	71.6	71.7	71.7	72.1	72.0	72.3	72.3	72.3	72.4	72.4	72.5	72.3
125	78.1	78.2	78.3	78.4	78.6	78.5	78.6	78.8	78.9	78.9	79.0	79.0	79.0
250	82.4	82.5	82.6	82.7	82.8	82.8	82.9	83.0	83.1	83.1	83.1	83.1	83.2
500	88.2	88.5	88.7	88.9	89.0	88.9	88.9	88.6	88.4	87.9	87.5	87.0	86.4
1000	85.2	85.7	86.1	86.4	86.6	86.3	86.0	85.4	84.7	84.1	83.6	83.4	82.6
2000	83.0	83.2	83.7	84.5	84.7	84.9	85.2	85.1	85.1	84.7	83.3	82.6	84.4
3000	84.7	82.9	82.5	80.9	80.8	82.3	84.6	86.2	85.2	82.6	81.2	82.4	85.0
4000	82.4	82.0	82.4	81.6	82.4	82.8	83.8	84.6	82.6	80.5	82.3	84.3	82.5
6000	82.5	81.3	82.5	82.5	77.1	73.4	82.0	81.7	74.4	79.5	83.0	78.1	84.8
8000	76.4	81.7	79.1	81.7	83.6	83.1	83.1	84.7	79.9	83.7	76.2	81.5	74.2

Table IV

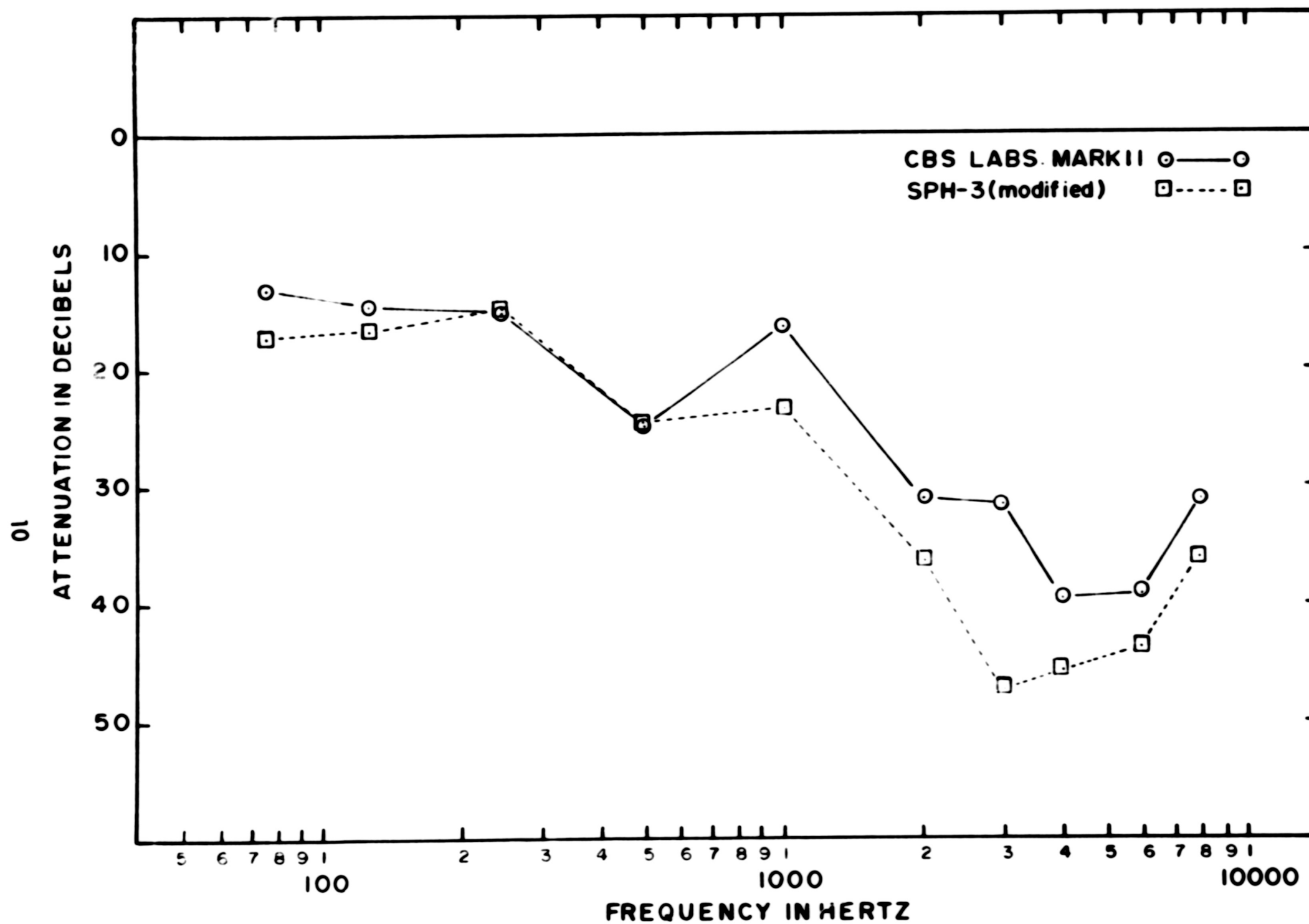
Mean Sound Pressure Level and Standard Deviation Values in Decibels (re 0.0002 Dyne/cm²) of Ambient Acoustic Noise in the Industrial Acoustics Company 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. Also Shown are System Noise Data of the Instrumentation Used in Measuring the Acoustic Noise.

1/3rd Octave-Band Center Frequencies in Hertz	System Noise		Room Noise	
	Mean SPL	Standard Equiv. Deviation	Mean SPL	Standard Deviation
25	18.13	3.15	29.36	2.97
31.5	16.13	2.80	28.68	3.07
40	16.00	2.90	29.48	2.95
50	14.76	2.42	30.36	2.55
63	15.83	2.12	31.97	1.52
80	12.87	2.17	14.36	1.95
100	11.38	1.70	16.81	0.37
125	9.70	1.75	28.93	0.85
160	9.32	1.50	9.88	1.25
200	8.02	1.42	10.99	1.22
250	6.14	1.25	17.81	1.22
310	5.58	1.32	11.56	0.67
400	4.86	1.17	14.21	0.32
500	4.18	0.82	4.58	0.95
630	2.65	1.22	4.46	0.80
800	2.08	0.90	4.55	0.90
1,000	1.59	0.60	2.40	1.12
1,250	2.68	1.20	4.17	0.65
1,600	1.26	1.00	3.22	1.22
2,000	0.96	1.22	2.18	0.95
2,500	0.31	1.27	1.78	0.27
3,150	0.73	1.22	8.97	0.80
4,000	0.58	1.25	4.16	0.47
5,000	1.46	0.80	2.53	1.15
6,300	1.75	0	2.98	1.15
8,000	2.35	1.07	1.90	0.60
10,000	1.75	0	4.30	1.72
12,500	2.49	1.15	4.25	0
16,000	4.25	0	4.26	0.15
20,000	4.25	0	4.62	0.87
A	36.75	0	36.75	0
B	34.25	0	35.65	1.25
C	46.75	0	49.32	0.70
Lin	56.75	0	56.75	0

Table V

Mean Real-Ear Sound Attenuation and Standard Deviation Values Obtained with the Army APH-5, the Army APH-5 (CBS) and the SPH-3 (Modified) Helmets.

Test Frequencies in Hertz	APH-5		APH-5 (CBS)		SPH-3 (Modified)	
	Mean Attenuation Values in Decibels	Standard Deviation in Decibels	Mean Attenuation Values in Decibels	Standard Deviation in Decibels	Mean Attenuation Values in Decibels	Standard Deviation in Decibels
75	11.34	5.03	13.12	4.92	17.20	3.50
125	10.86	4.55	14.69	4.70	16.91	3.70
250	5.98	4.15	15.19	3.25	14.95	3.36
500	7.11	3.52	24.99	5.27	24.66	3.07
1000	15.37	4.84	16.53	5.21	23.38	4.89
2000	29.11	5.61	31.11	4.96	36.40	5.11
3000	43.00	5.26	31.94	6.17	47.32	5.86
4000	46.26	7.07	39.91	6.75	45.94	5.77
6000	45.83	6.92	39.22	9.10	43.79	5.29
8000	35.97	10.83	31.15	6.09	36.24	7.82



MEAN REAL-EAR SOUND ATTENUATION CHARACTERISTICS OF CBS LABORATORIES' MARK II EARPHONE ENCLOSURE AND SPH-3 HELMET

Figure 2

Table VI

Decile Values in Decibels for Mean Real-Ear
Attenuation Data of 36 Ear Protective Devices.

<u>Deciles</u>	<u>75 Hz*</u>	<u>125 Hz</u>	<u>250 Hz</u>	<u>500 Hz</u>	<u>1000 Hz</u>	<u>2000 Hz</u>	<u>4000 Hz</u>	<u>8000 Hz</u>
D ₁	2.3	0.3	0.0	3.8	2.4	15.8	27.8	24.8
D ₂	4.1	2.9	3.1	7.1	11.7	19.1	29.6	26.6
D ₃	5.9	4.4	4.4	10.3	15.4	21.3	31.3	28.4
D ₄	7.3	6.9	6.2	13.7	18.9	25.6	32.9	30.2
D ₅	9.5	9.0	9.5	16.5	22.0	26.5	34.7	32.5
D ₆	10.9	11.1	13.7	18.8	25.8	29.3	35.8	34.0
D ₇	13.9	14.1	15.6	24.7	30.2	32.7	37.6	35.9
D ₈	15.2	15.4	18.3	29.3	32.3	34.8	38.4	37.4
D ₉	17.1	18.7	20.9	30.3	35.6	36.7	41.9	38.3

* Computed from data of 34 ear protective devices.

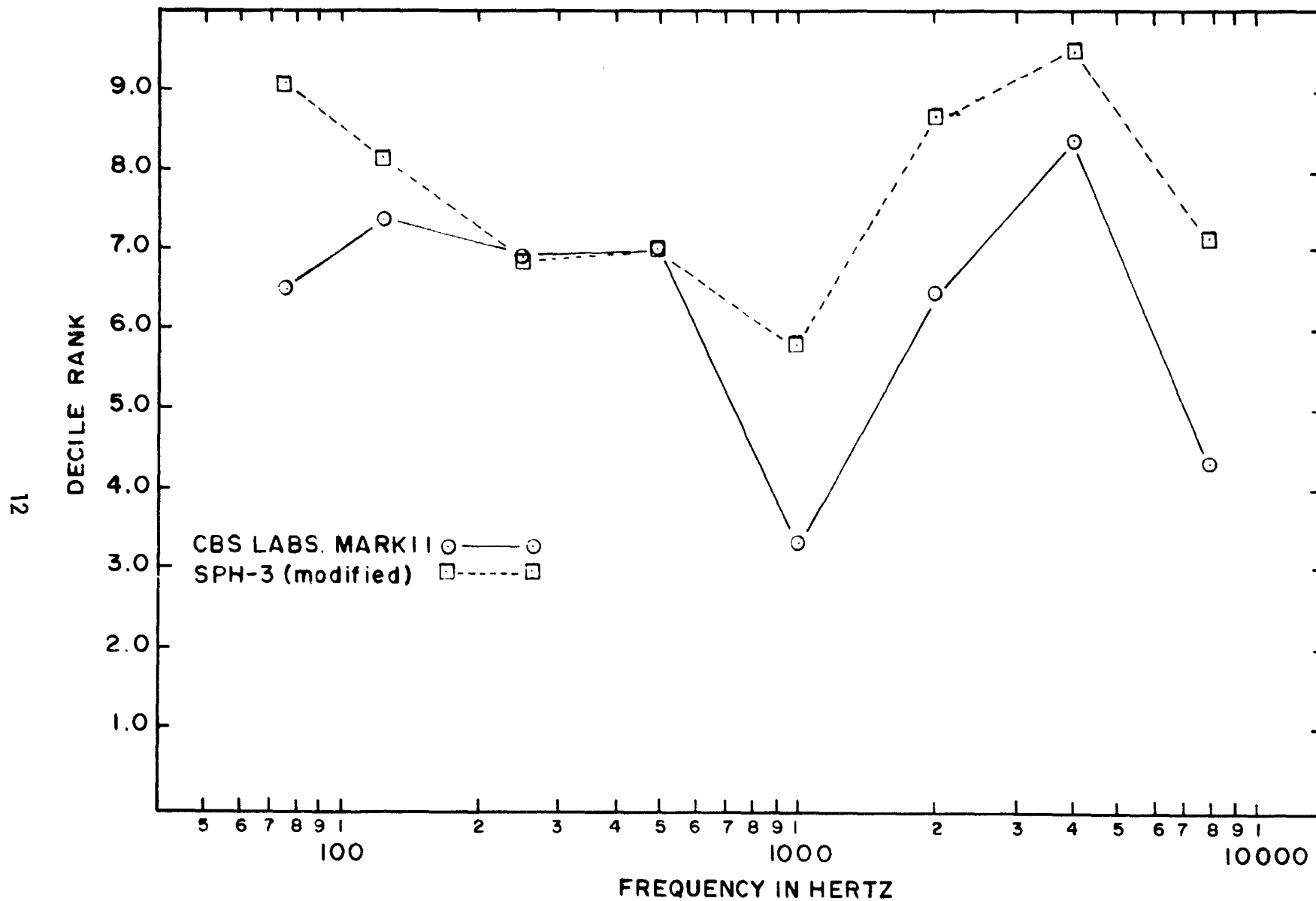


Figure 3

DECILE RANKS OF MEAN REAL-EAR ATTENUATION VALUES OBTAINED WITH
CBS LABORATORIES' MARK II EARPHONE ENCLOSURES AND AN SPH-3 HELMET

frequencies from 2K Hz and above.

Comparison of the MARK II with the APH-5 helmet values given in Table V shows that there is less than 2 db difference between the value yielded by the APH-5 with normal earmuffs and the CBS MARK II. At 125, 250 and 500, the MARK II is, of course, much more efficient and offers much better protection than the standard APH-5. At 1K Hz the difference between the two is no greater than 1 db which would be hardly significant. At 2K Hz the MARK II is approximately 2 db higher, but at all higher frequencies the standard APH-5 muff is a superior attenuator of the range of frequencies which are critical for the prevention of permanent hearing loss.

An overall evaluation of the MARK II efficiency is that it is a device that has provided improved real-ear attenuation characteristics in the standard APH-5 at the lower frequencies at 500 Hz and below, but it is actually inferior to the standard APH-5 muff at the high frequencies around 4K Hz which is a critical area for the human ear. At no frequency does it really outperform the SPH-3 (Modified). The attenuation values obtained with the MARK II are slightly higher at 250 and 500 Hz, but at all other points the values are less than those obtained with the highly efficient SPH-3 (Modified). These minor variations of .24 and .33 db at 250 and 500 Hz are certainly not significant improvements over the SPH-3 (Modified).

CONCLUSION AND RECOMMENDATIONS.

Real-ear sound attenuation characteristics of the CBS Laboratories' MARK II earphone inclosure were determined by standard procedures and equipment recommended by ASI Z24.22-1957. Ten subjects were tested three times each. This is the minimum amount required by the ASI specifications. Comparisons of the results of these tests were made with the results obtained in USAARL Reports 67-6 and 67-8 on the attenuation characteristics of the standard APH-5 earmuff and the Navy SPH-3 (Modified) helmet. These comparisons show that:

- 1) The SPH-3 (Modified) yielded superior real-ear attenuation values at all test frequencies except 250 Hz and 500 Hz.
- 2) At 250 Hz and 500 Hz, the values were almost identical.
- 3) The MARK II showed an exceptional weakness at 1K Hz for a muff that was specifically designed for attenuation of sound.

- 4) The MARK II earphone inclosure improved the attenuation characteristics of the APH-5 in the lower range from 75 to 500 Hz and approximately comparable results from 500 through 2K Hz, but yields an inferior response for the high frequencies from 3K through 8K Hz.

In view of these findings, it is acknowledged that in certain types of noise the MARK II is superior to the standard APH-5 earmuff for attenuating low frequencies which might interfere with communications and may even provide adequate attenuation at the high frequencies. The MARK II was not superior to the SPH-3 (Modified) performance at any of the ten test frequencies. At 250 Hz and 500 Hz the two devices yielded practically identical values, which is hardly enough to consider it an improved protector in view of the inferior values at all other test frequencies. The lack of efficiency at 1K Hz is perhaps the greatest drawback of this device.

The results of this test show unequivocally that this attempt to provide the standard Army APH-5 with sound attenuation characteristics superior to the SPH-3 (Modified) has failed. The SPH-3 (Modified) remains one of the most efficient attenuators of sound in a helmet configuration. It is therefore recommended that the SPH-3 (Modified) or SPH-4 (improved version of the SPH-3 modified) be the standard for U. S. Army Aviation personnel equipment. The additional advantages of this helmet in other respects, combined with its attenuation capability, make it the most effective device available at this time for maximum comfort, aural protection and safety.

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